Landsat Radiometric Calibration

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Landsat Calibration Scientist

Objectives

- Working with USGS, insure the scientific integrity of the Landsat data
  - Radiometric characterization and calibration
    - Consistency of calibration of data products over life of missions
    - Landsat 7 ETM+, Landsat-5 TM ongoing
    - Landsat 4, 5 TM historical

Approach

- Team Effort
  - USGS
    - IAS (operational calibration, systematic trending, analyses)
      - L7 ETM+ (IAS in production since launch)
      - L5 TM (TMIAS in development with SDSU)
  - NASA
    - LPSO (radiometric analyses and calibration, research and development)
    - LCLUC calibration team/vicarious team
      - University of Arizona (Thome) - reflective
      - JPL (Palluconi/Hook) - thermal
      - Rochester Institute of Technology (Schott)- thermal, historical
      - South Dakota State University (Helder) reflective, characterization, historical

LPSO Calibration Personnel

- B. L. Markham
- J. L. Barker
- J. Sun
- J. Miller
- J. Barsi
- E. Kaita

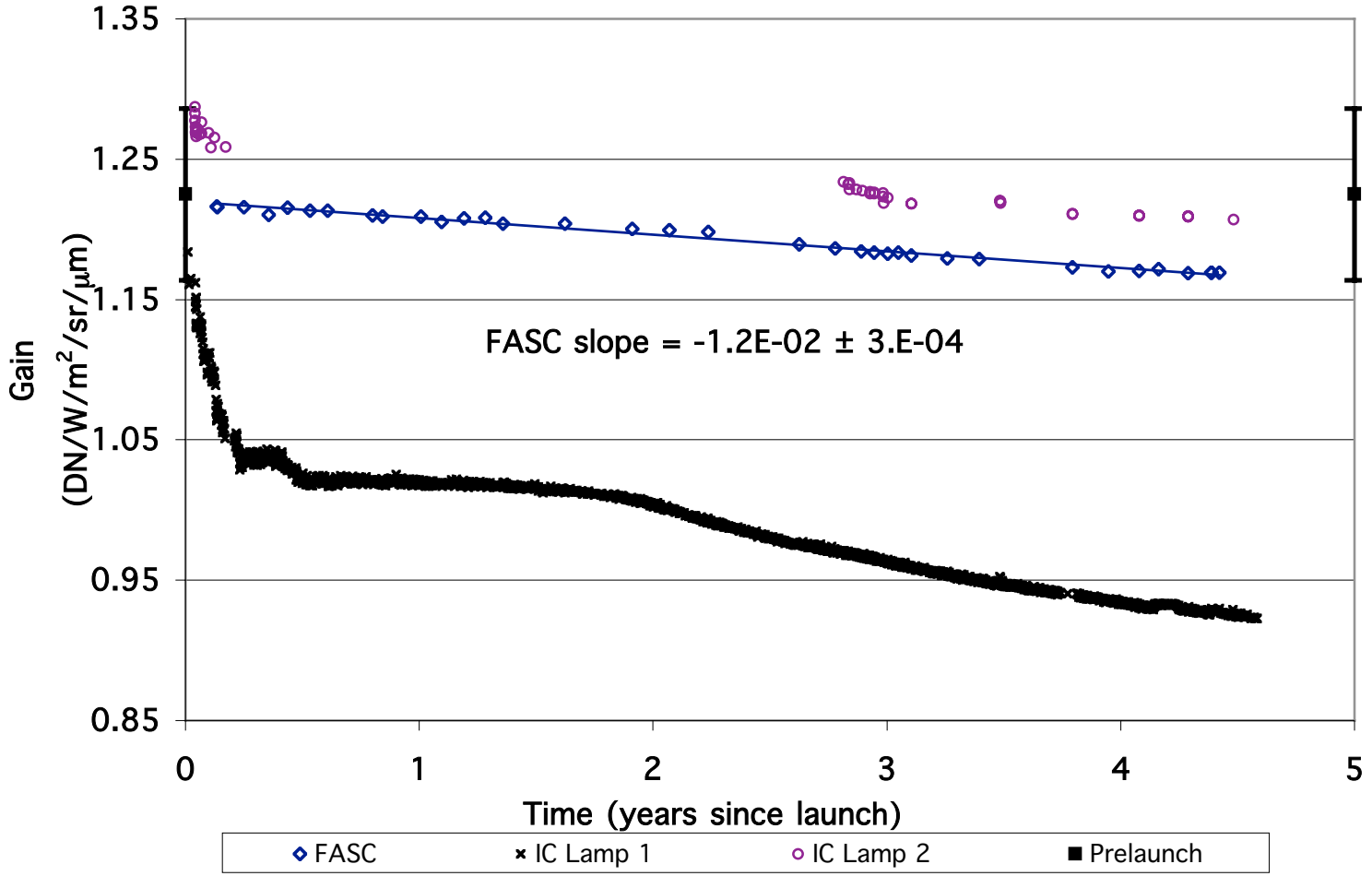
Highlights

- Landsat-7 ETM+ reflective bands very stable, trends on order of 0.3%/year
- Landsat-7 ETM+ thermal band very stable-no significant gain change with time
  - 1K (1 σ) scatter relative to ground measurements
  - SLC failure may have introduced bias (<1K)
- Landsat-5 TM reflective band calibration procedure has been updated
  - Now internally consistent and cross calibrated with Landsat-7 ETM+
- Landsat-5 TM thermal band data generally well calibrated
  - has greater scatter than ETM+ relative to ground measurements ~2K
  - May be some calibration sensitivity to instrument temperature
  - Possible cause for poorly calibrated data determined
- Landsat-4 TM calibration reconstruction in progress
- Special issue of TGARS on Landsat geometric and radiometric performance in preparation for December 2004

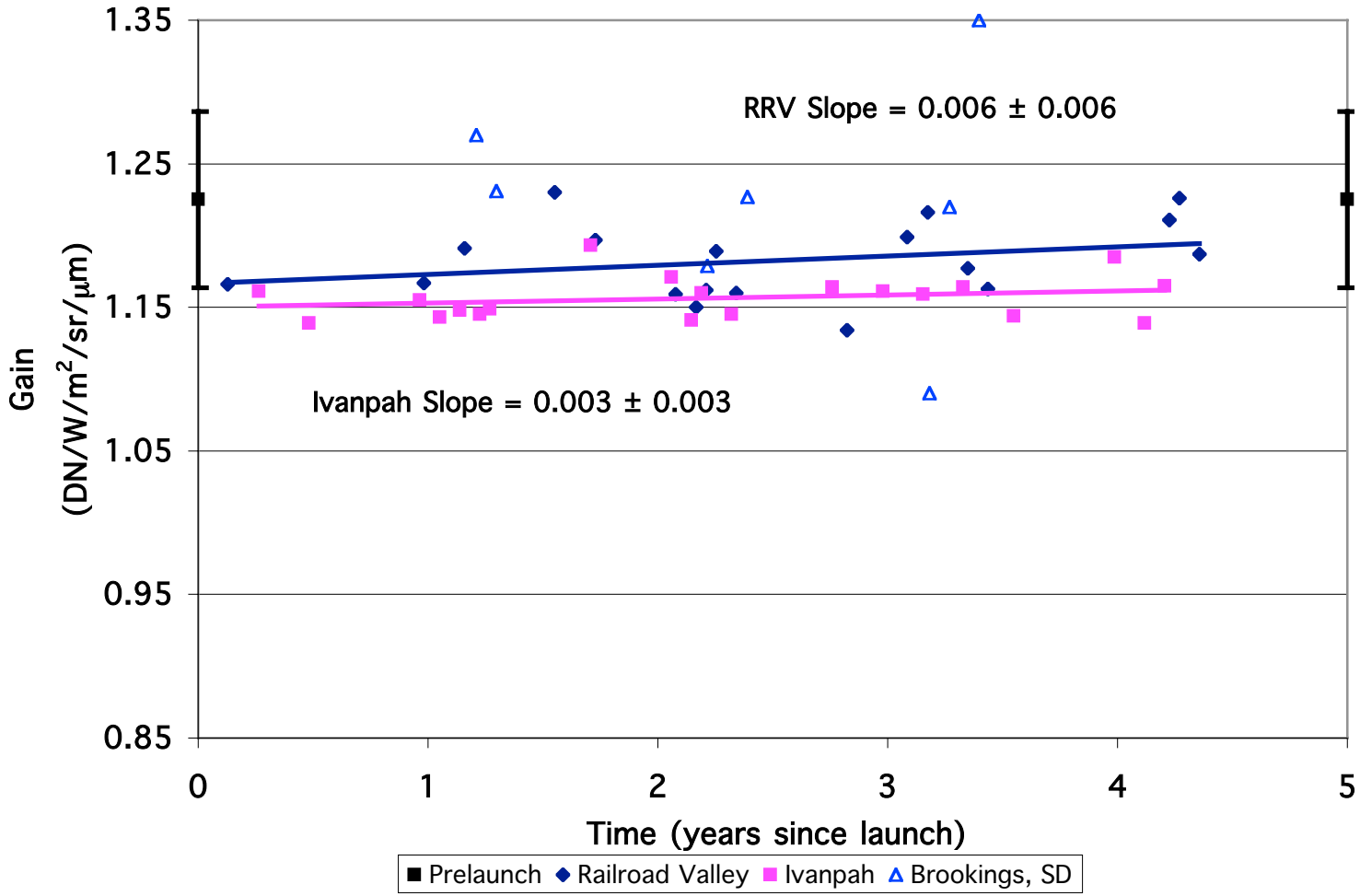
Landsat-7 ETM+

- Recurring activities
  - ETM+ calibration monitoring
    - Reflective
      - On-board calibration trending
      - Vicarious calibration trending
      - Integrated results
    - Thermal
      - On board calibration trending
      - Vicarious calibration results

Landsat-7 ETM+ Band 1 On-Board Calibrator Results



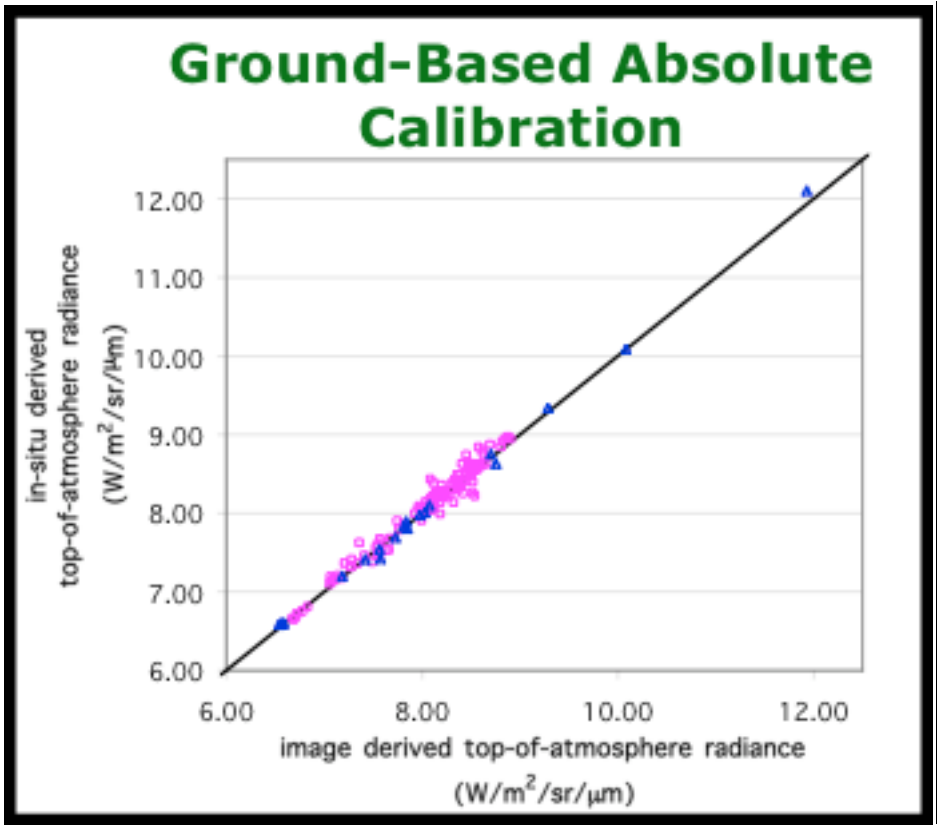
Landsat-7 ETM+ Band 1 Vicarious calibration results

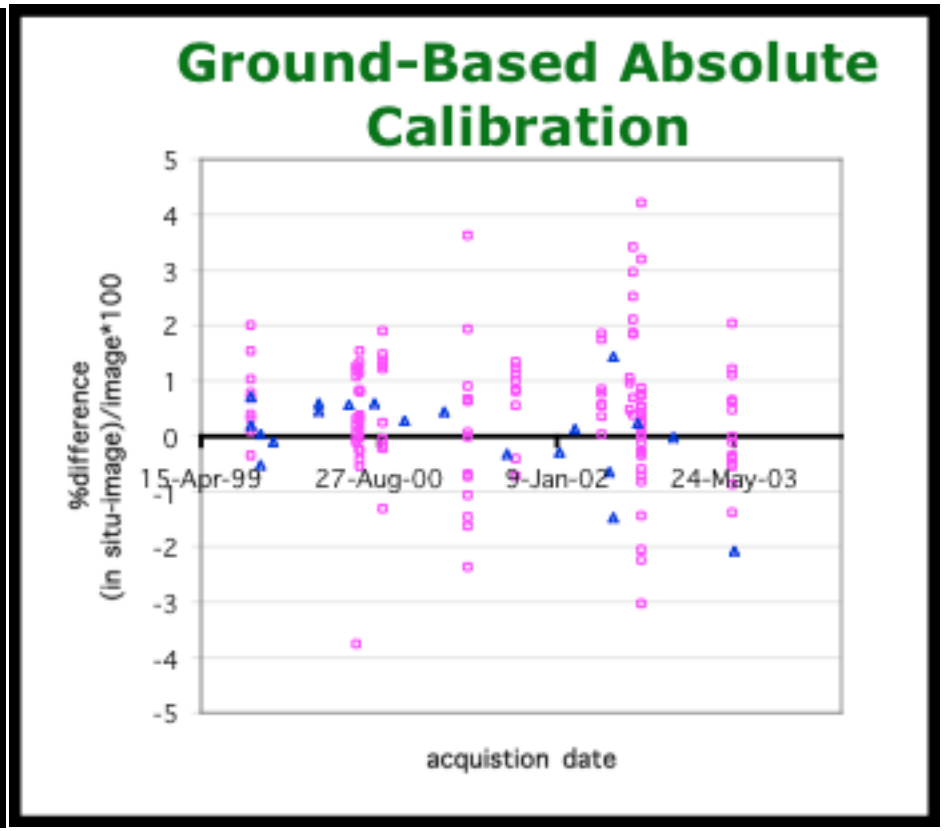


Current "Best" Estimates of ETM+ Gain Changes

Band	Weighted Average Slope (Gain/yr)		Weighted Average Slope Uncertainty (Gain/yr)		Statistical Significance
	Absolute [High Gain] (W/m^2 sr μm)	Relative (% of Pre-launch)	Absolute [High Gain] (W/m^2 sr μm)	Relative (% of Pre-launch)	t-Value
1	-2E-03	-0.2	1E-03	-0.1	1.4
2	-4E-03	-0.3	1E-03	-0.1	2.6
3	-3E-03	-0.2	2E-03	-0.1	2.0
4	-0E-03	-0.0	2E-03	-0.2	0.2
5	-4E-02	-0.5	9E-03	-0.1	4.4
7	-9 E-02	-0.4	4E-02	-0.2	2.4
8*	-4E-03	-0.4	2E-03	-0.2	2.3

Landsat-7 ETM+ Thermal Band Vicarious Calibration





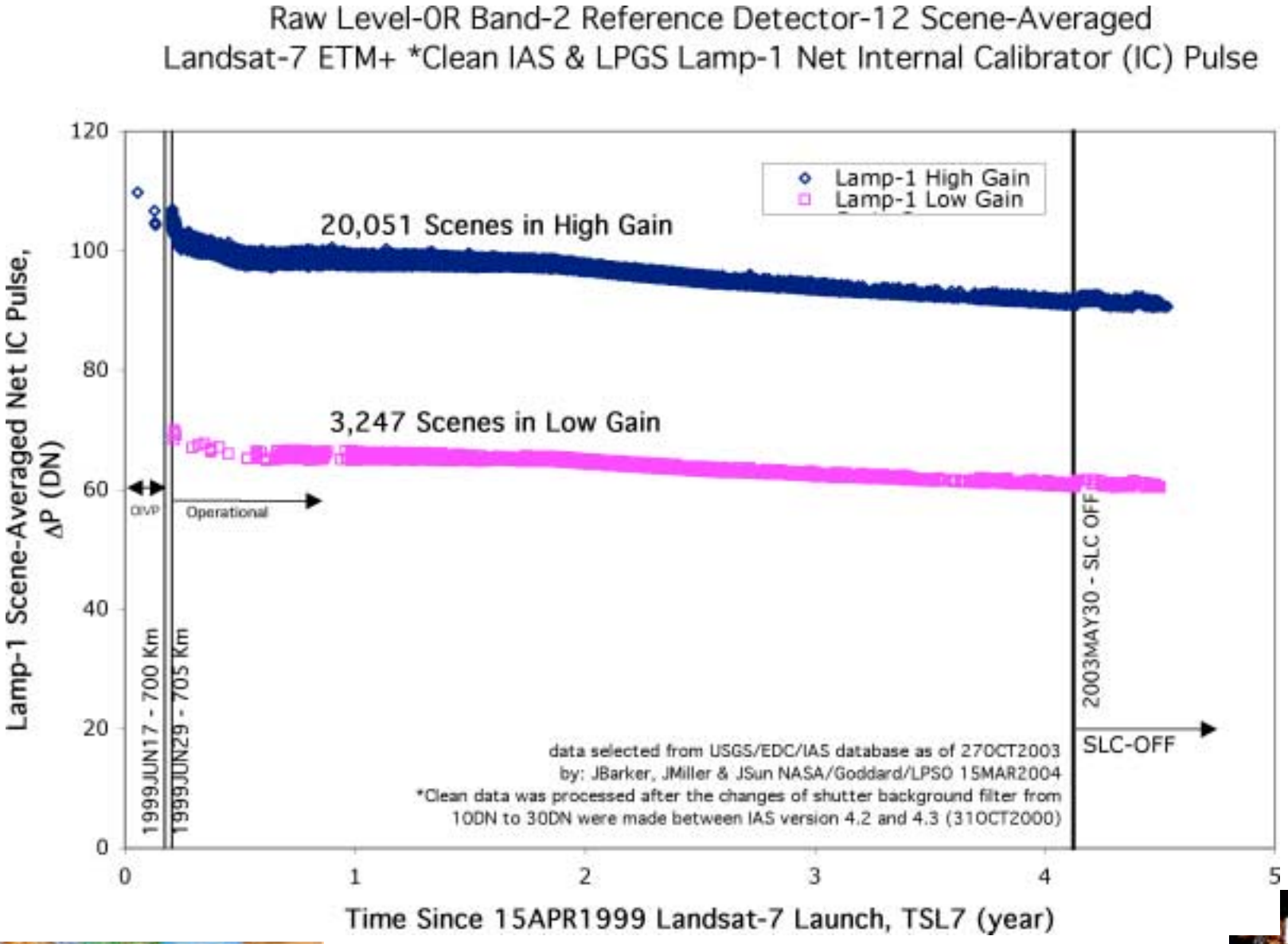
remaining RMS

0.13 W/m²/sr/μm or 1.0 K

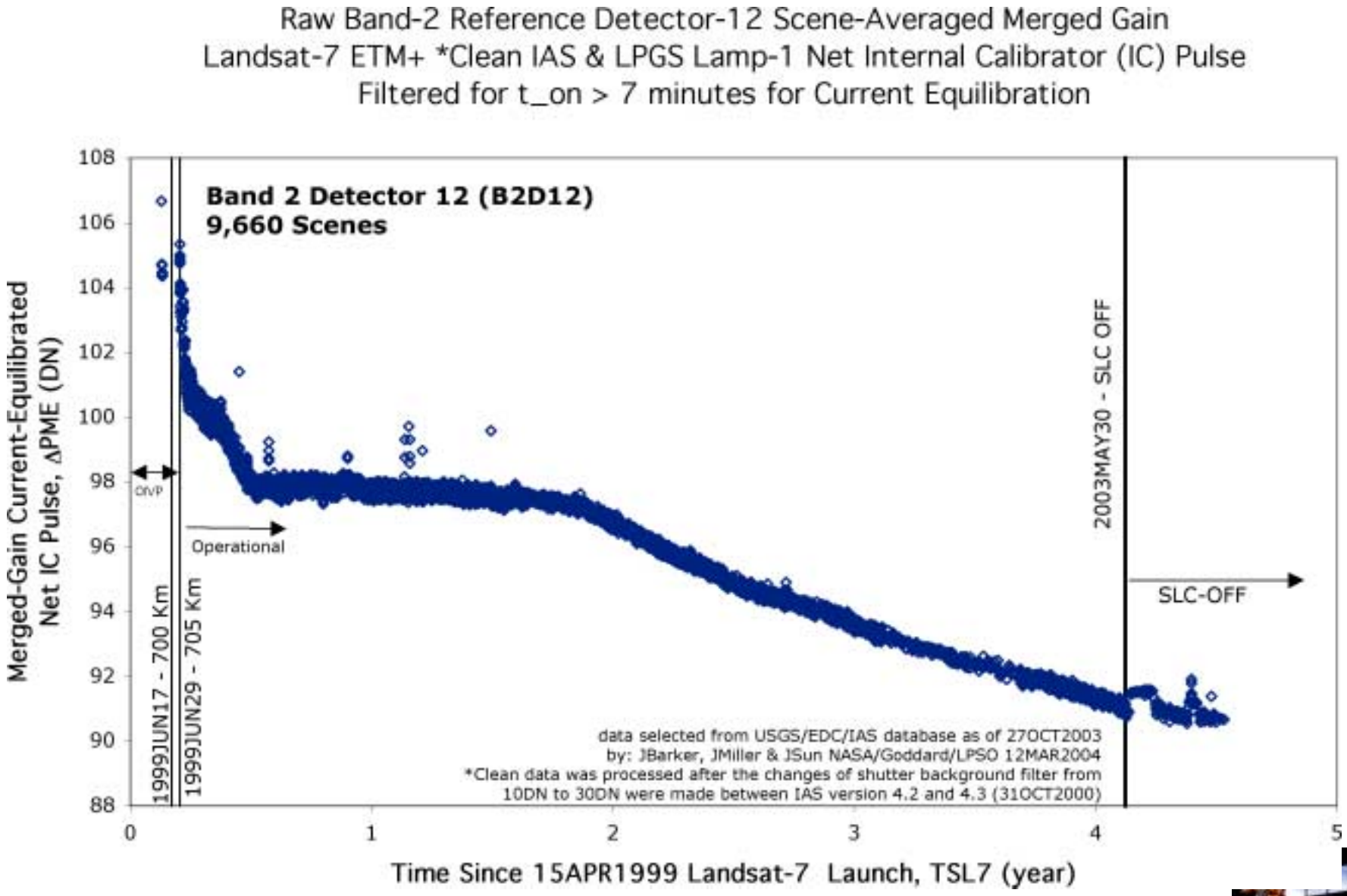
L7 ETM+ Special Studies/Algorithm Development

- Algorithms to improve usability of on-board calibration systems
  - Internal Calibrator
    - Environmental sensitivities
      - Warm-up
      - Temperature,current
  - Full Aperture Solar Calibrator
    - Degradation models

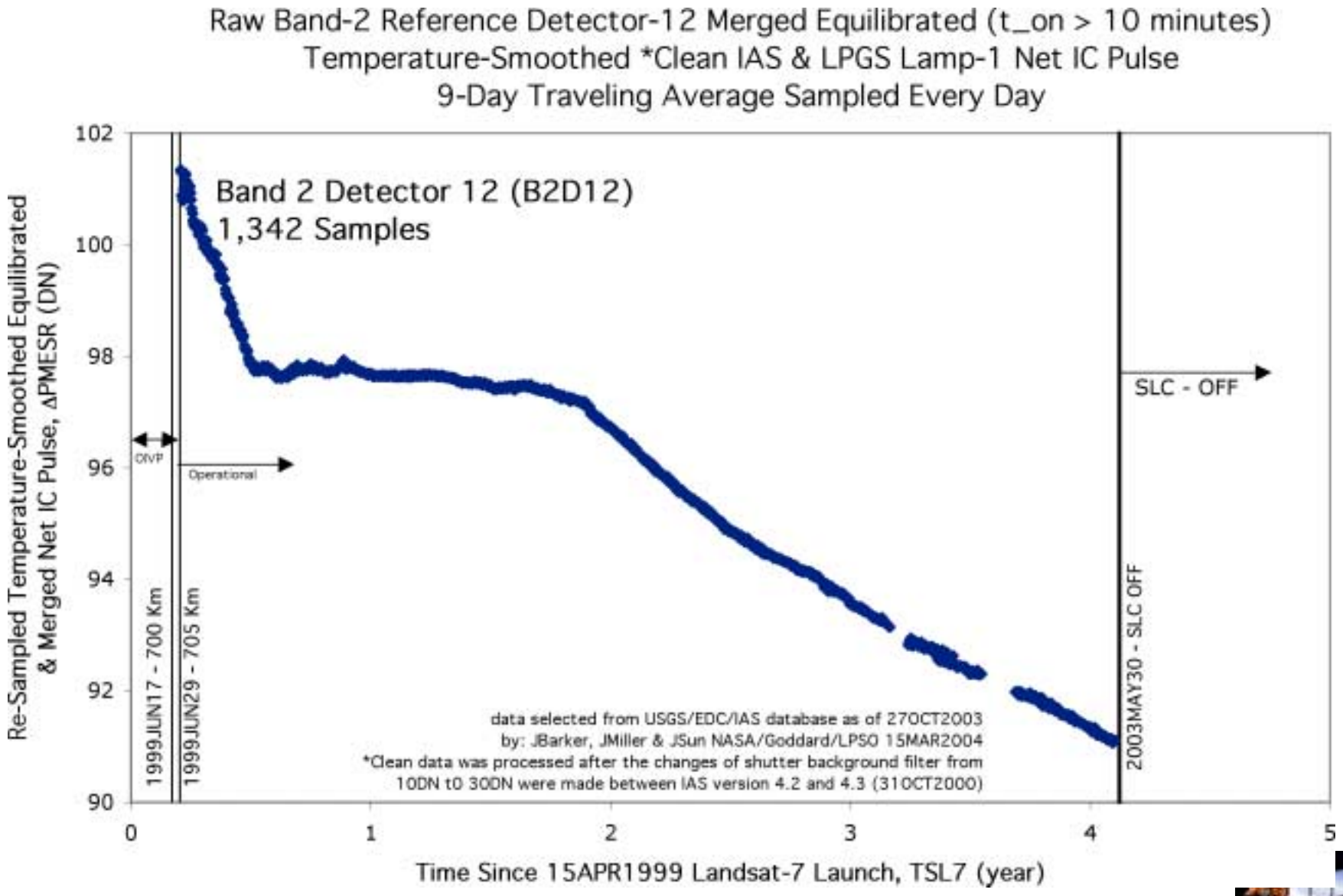
ETM+ Band 2 Raw Internal Calibrator Responses



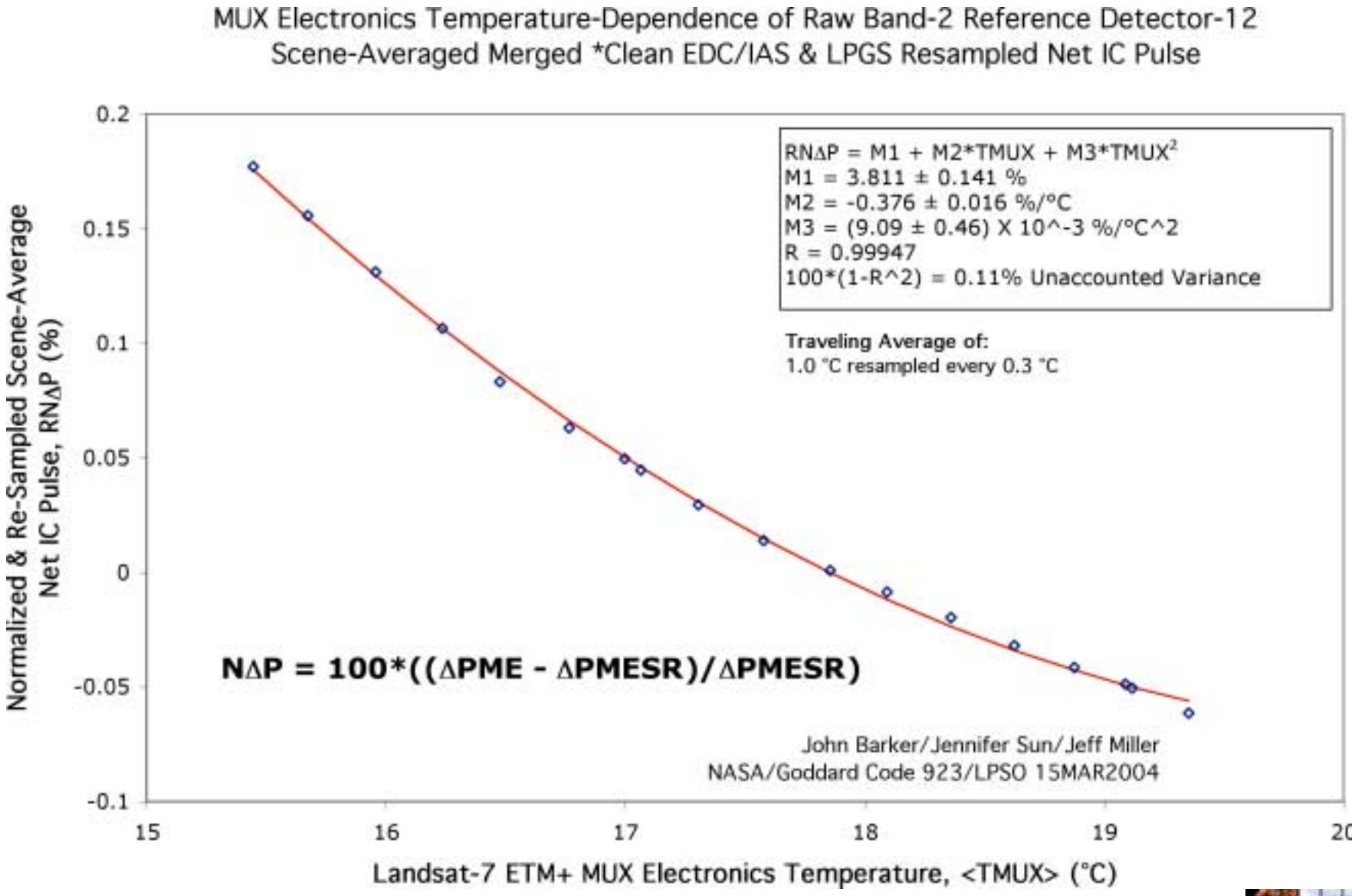
ETM+ Band 2 Merged, and Filtered IC Responses



ETM+ Band 2 Temperature Smoothed IC Responses



ETM+ Band 2 IC Temperature Sensitivity

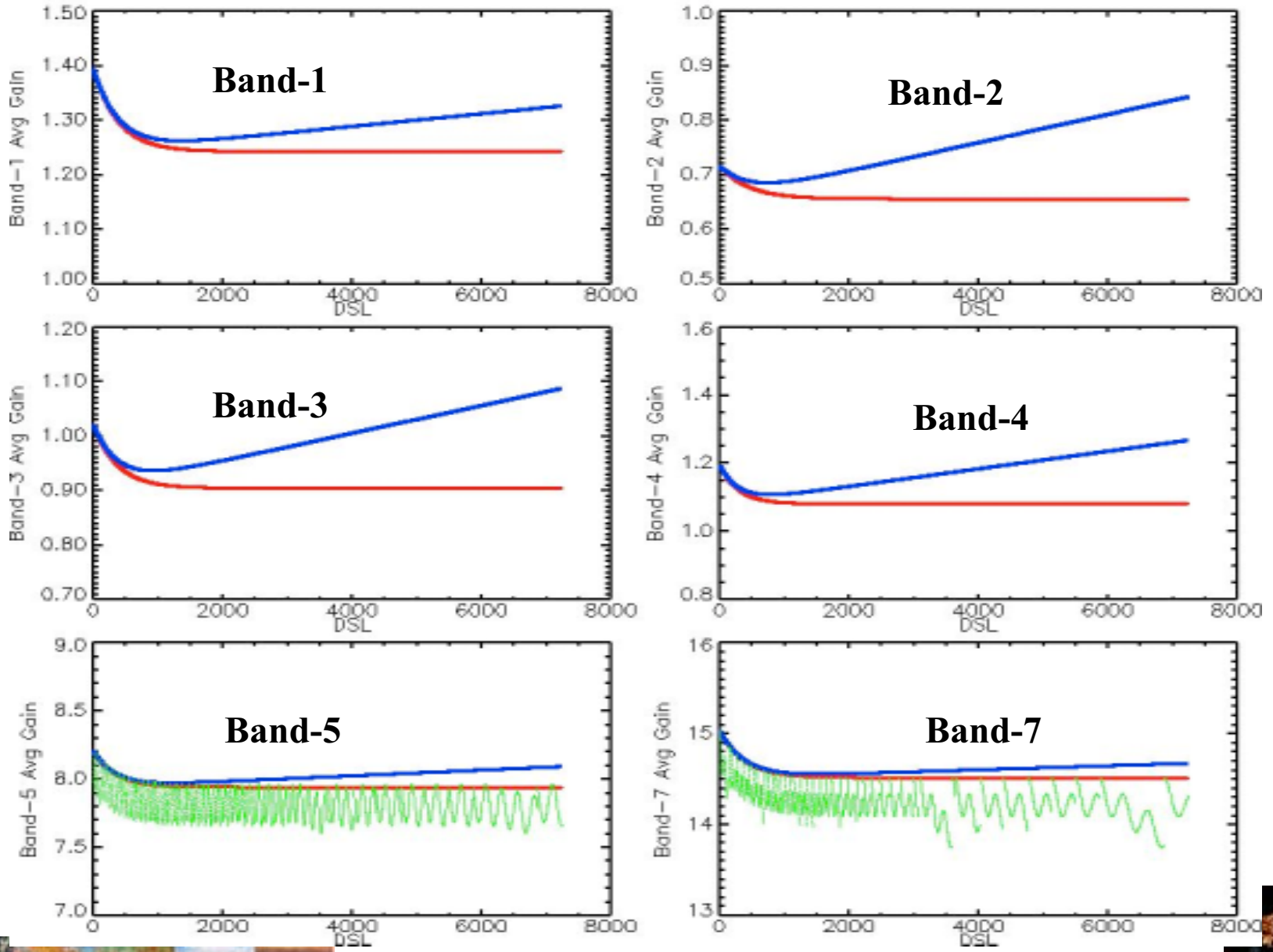


'Sun

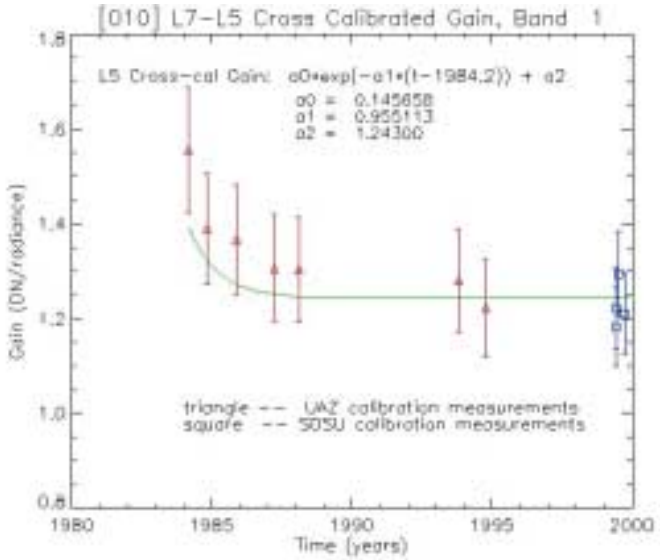
Landsat-5 TM Reflective Band Calibration Reconstruction

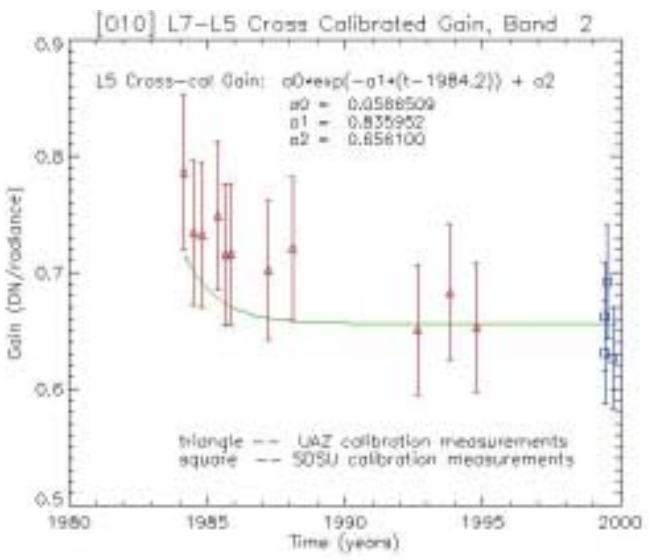
- Best internal lamp data modeled
- Initial degradation deemed real instrument effect; later increase a Lamp effect
- Outgassing effects modeled for SWIR bands
- Model tied to Landsat-7 cross calibration
- Compared to vicarious calibrations
- Compared to invariant sites
- Daily band average gain values entered into processing file
- Updated calibration processing implemented May 2003 at EDC

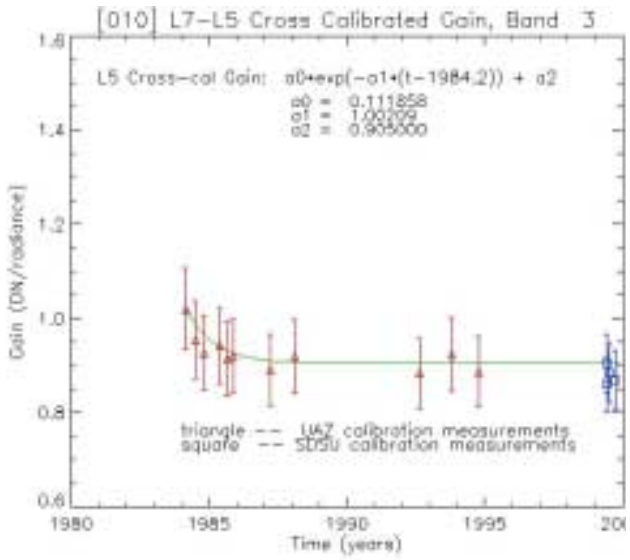
Landsat-5 TM Lifetime Gain Modeling

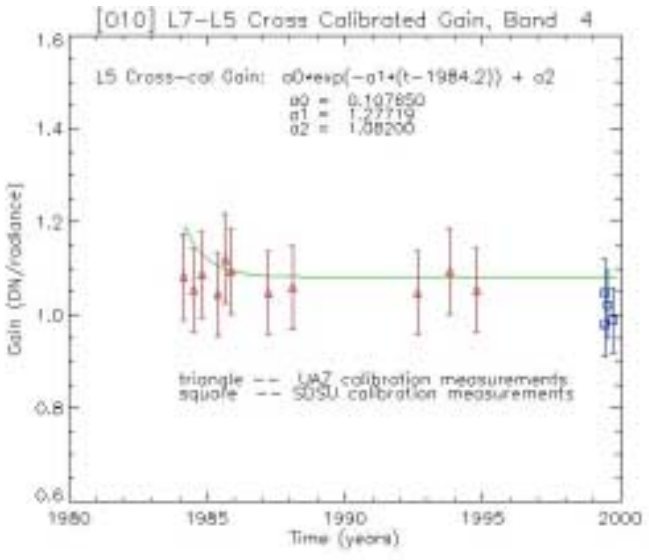


Comparison to Vicarious Calibration Data

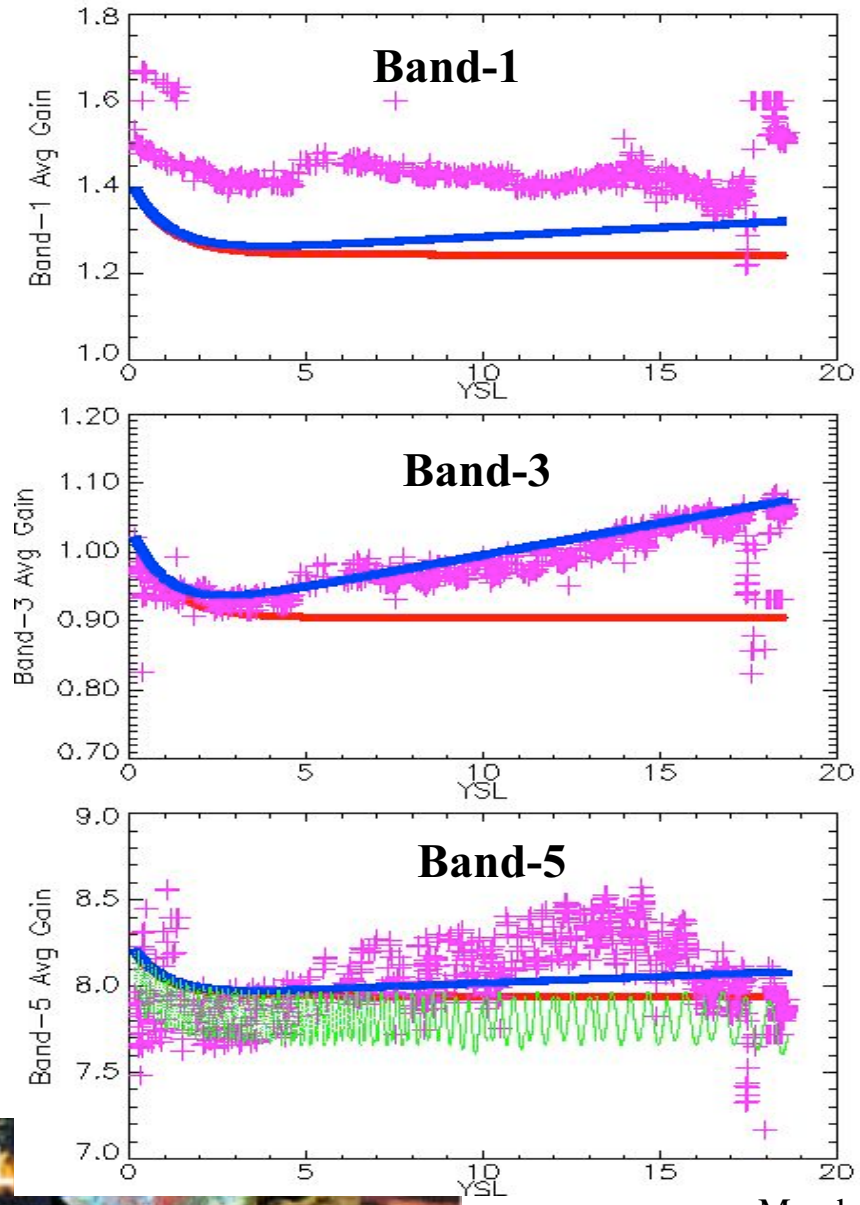


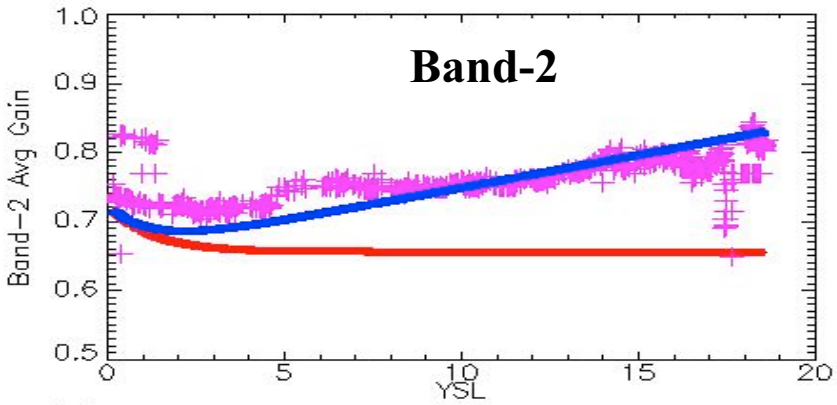


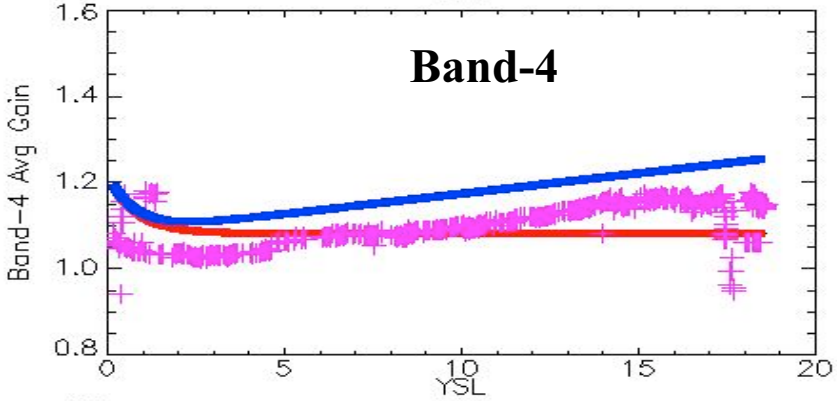


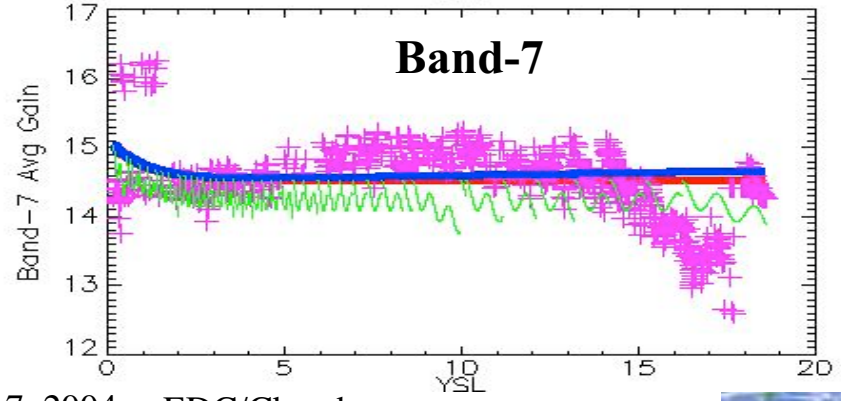


Improved Landsat-5 TM Calibration









Future Plans

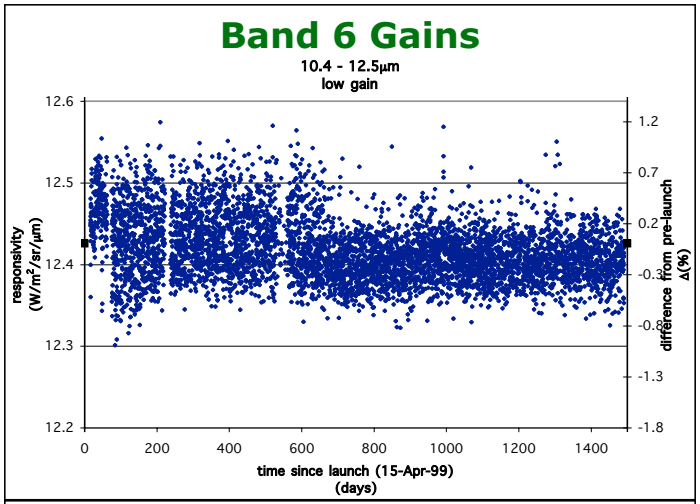
- Resolve thermal band calibration issues
- Complete Landsat-4 TM calibration reconstruction
- Continue special studies/algorithm development - to improve calibrator usability
- Maintain radiometric calibration oversight
- Continue transition of personnel to LDCM
- Continue vicarious calibration activities

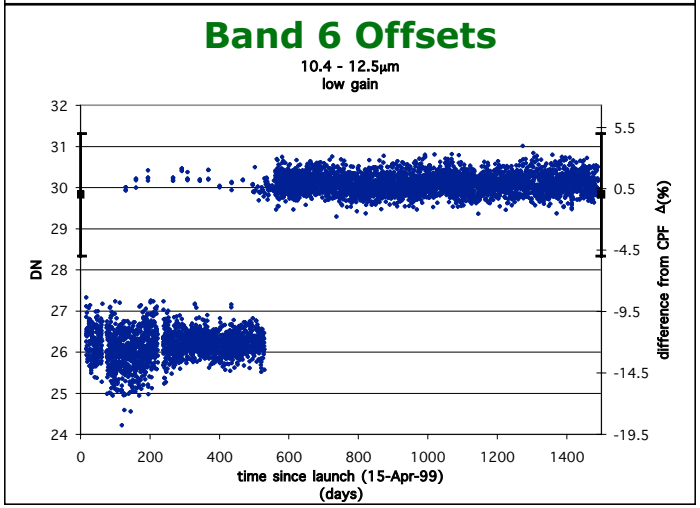
Back-up Slides

Highlights

- Landsat - 7 ETM+
  - Recurring Activities
  - Special Studies
- Landsat - 4/5 TM
  - L5 TM Calibration Reconstruction
    - Absolute
    - Thermal
  - L4 TM Analyses Status

ETM+ Thermal Band gains - Internal Calibrator based





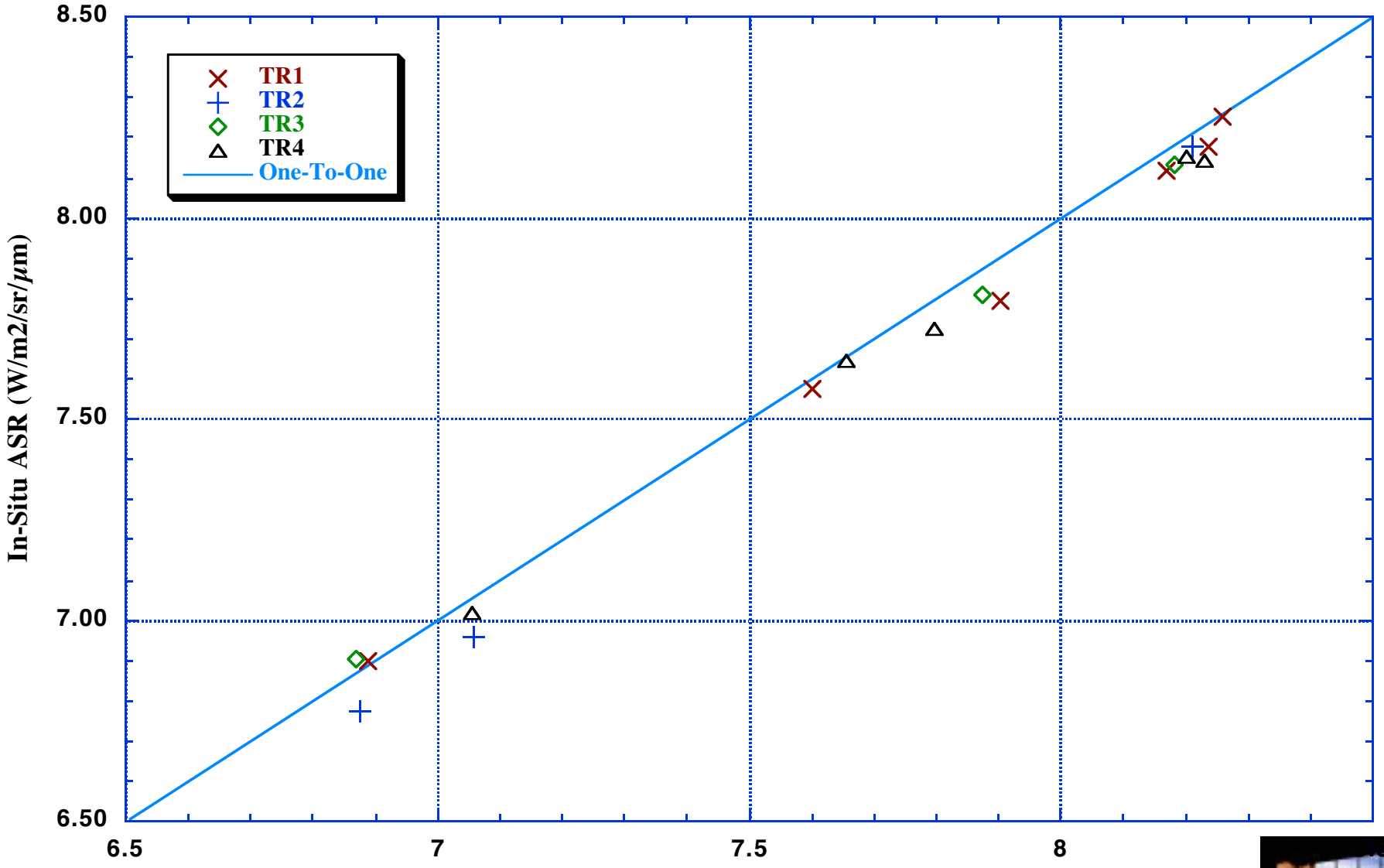
- Gain
  - slope change per year:
    0.01% ± 0.01
- Offset
  - slope change per year
    -0.03% ± 0.02

(10-Jun-03 = 1516 days since launch)

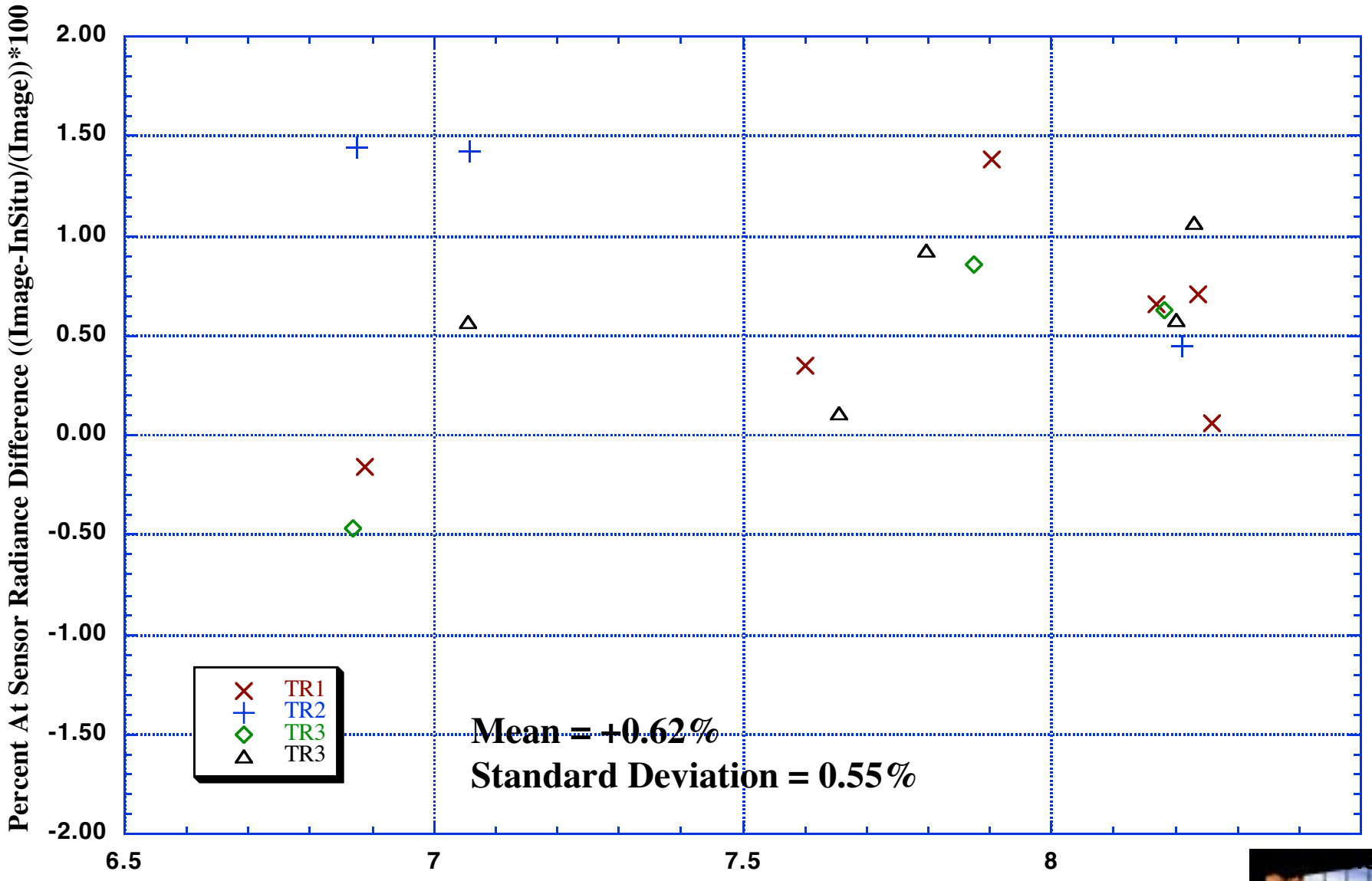
ETM+ Thermal Band Calibration

- Pre-SLC off operation, ~1K RMS scatter, no apparent bias
- Post-SLC off operation, ~1K bias (high) relative to JPL data, RIT data not initially consistent
- Flaw found in CPF coefficients for ETM+ thermistor calibration--caused most of initial bias in ETM+ thermal cal - since corrected
  - Unclear if any impact on SLC off calibration bias

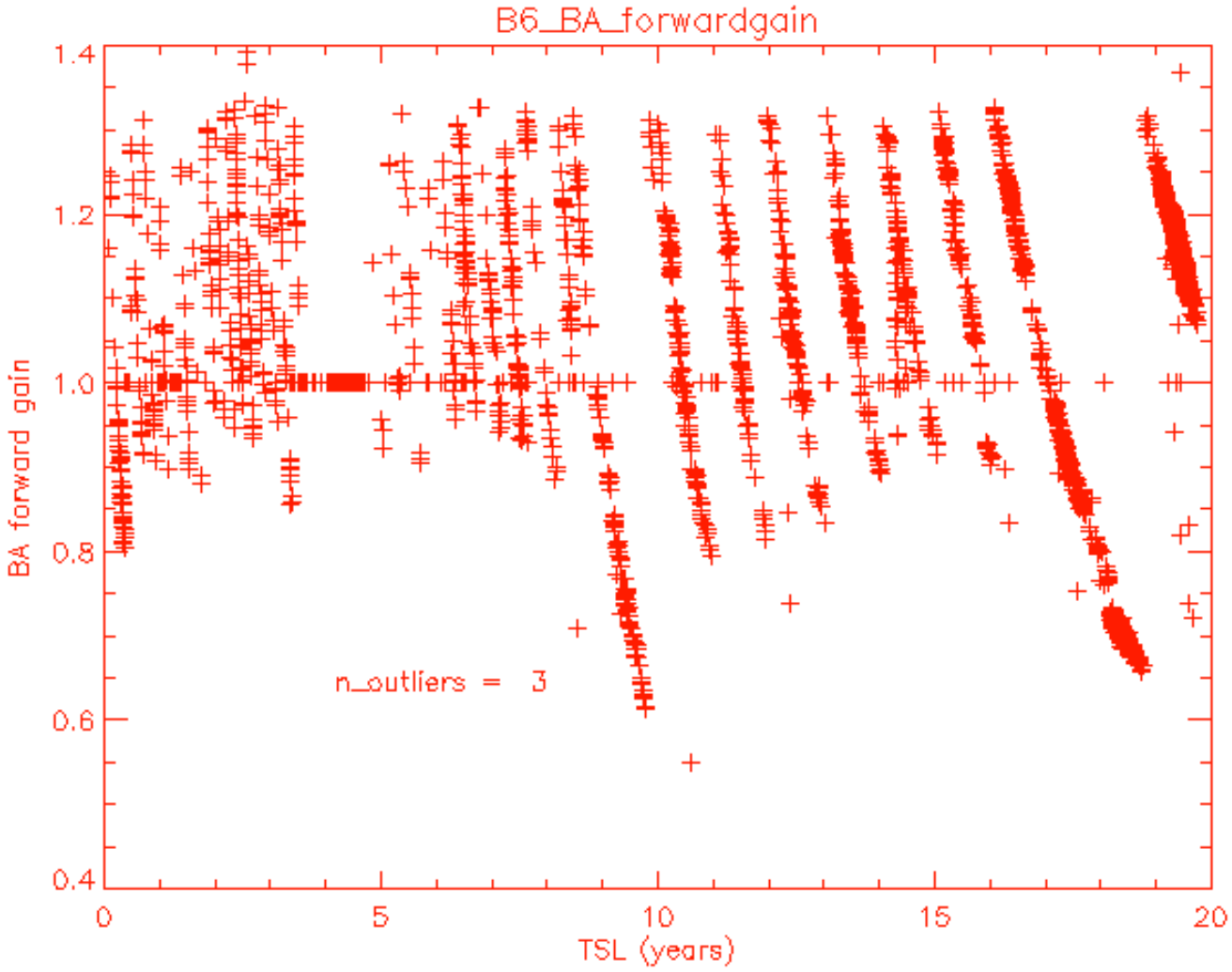
In-Situ vs Image Derived At Sensor Radiance For ETM+ Band 6 For 7 Dates From 9 June Thru 2 December 2003 For Lake Tahoe Rafts



Percent Radiance Difference Versus Image At Sensor Radiance For ETM+ Band 6 For 7 Dates From 9 June Thru 02 December 2003 For Lake Tahoe Rafts

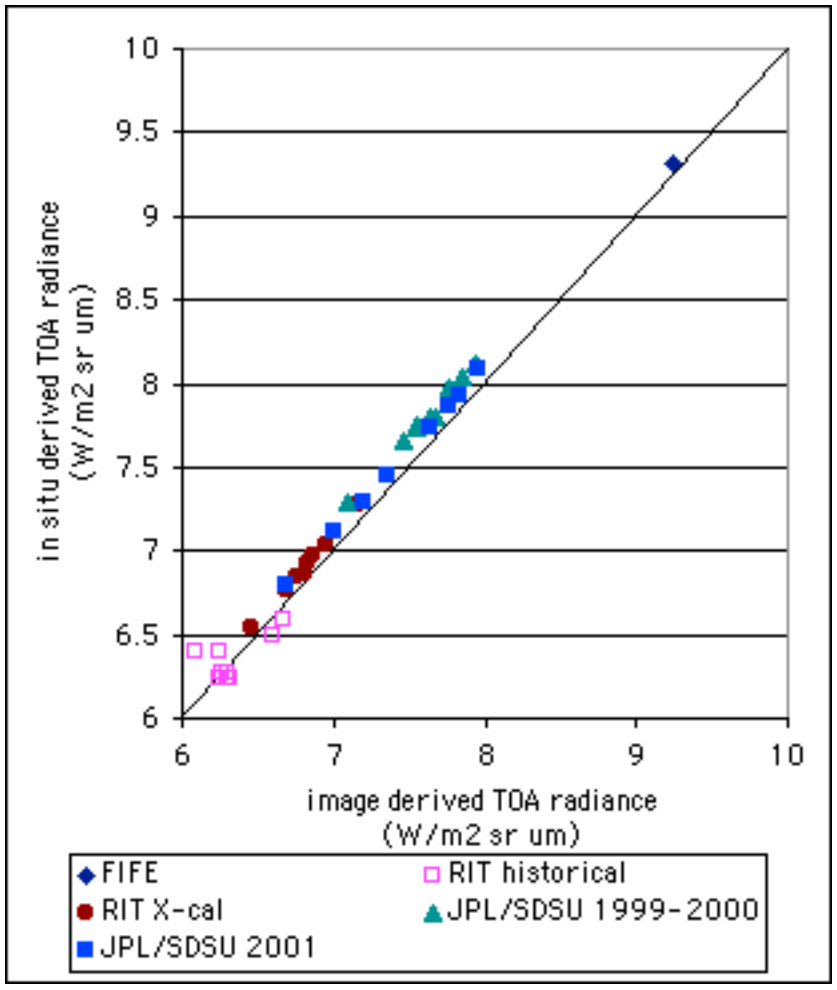


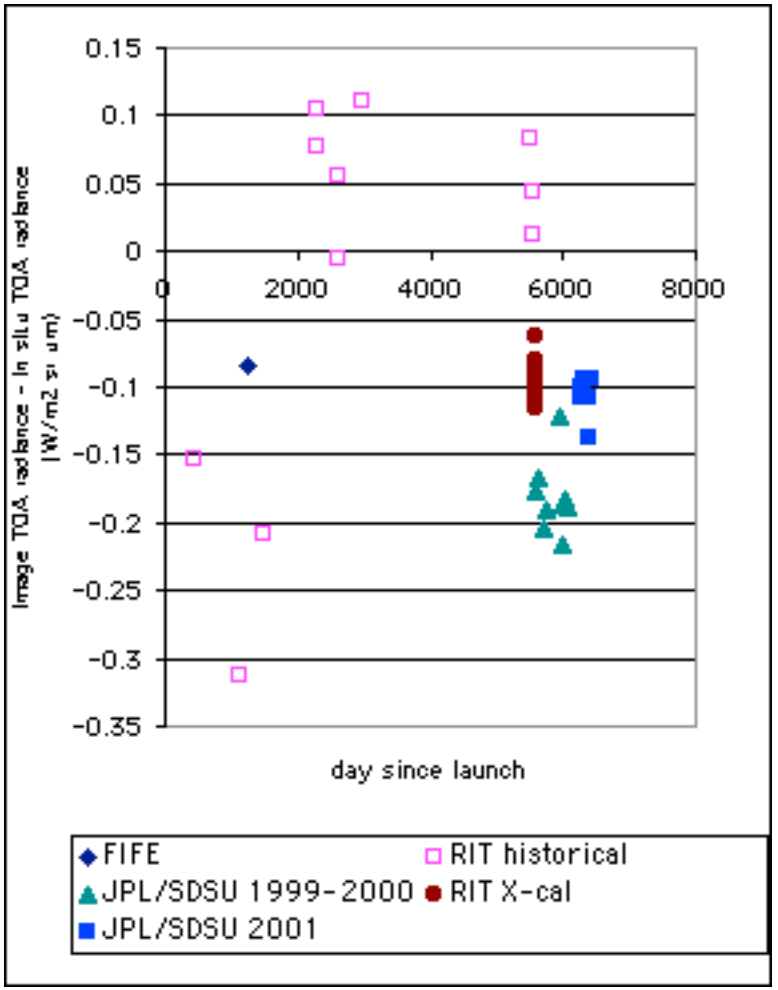
Landsat-5 Thermal Band Internal Calibrator Gains



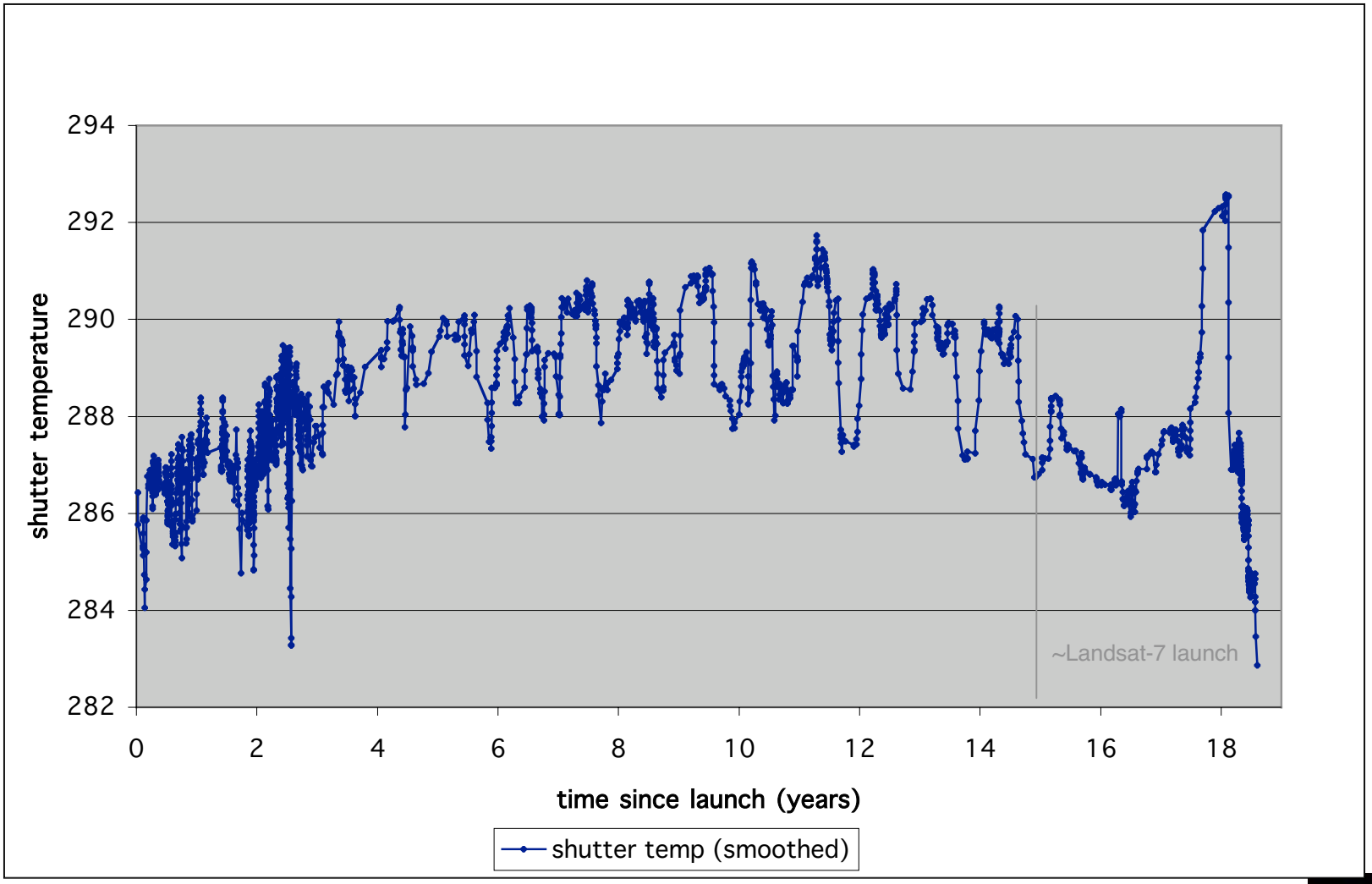
(10-Dec-03 = 19.77 years since launch)

L5 Thermal Band Vicarious Calibrations

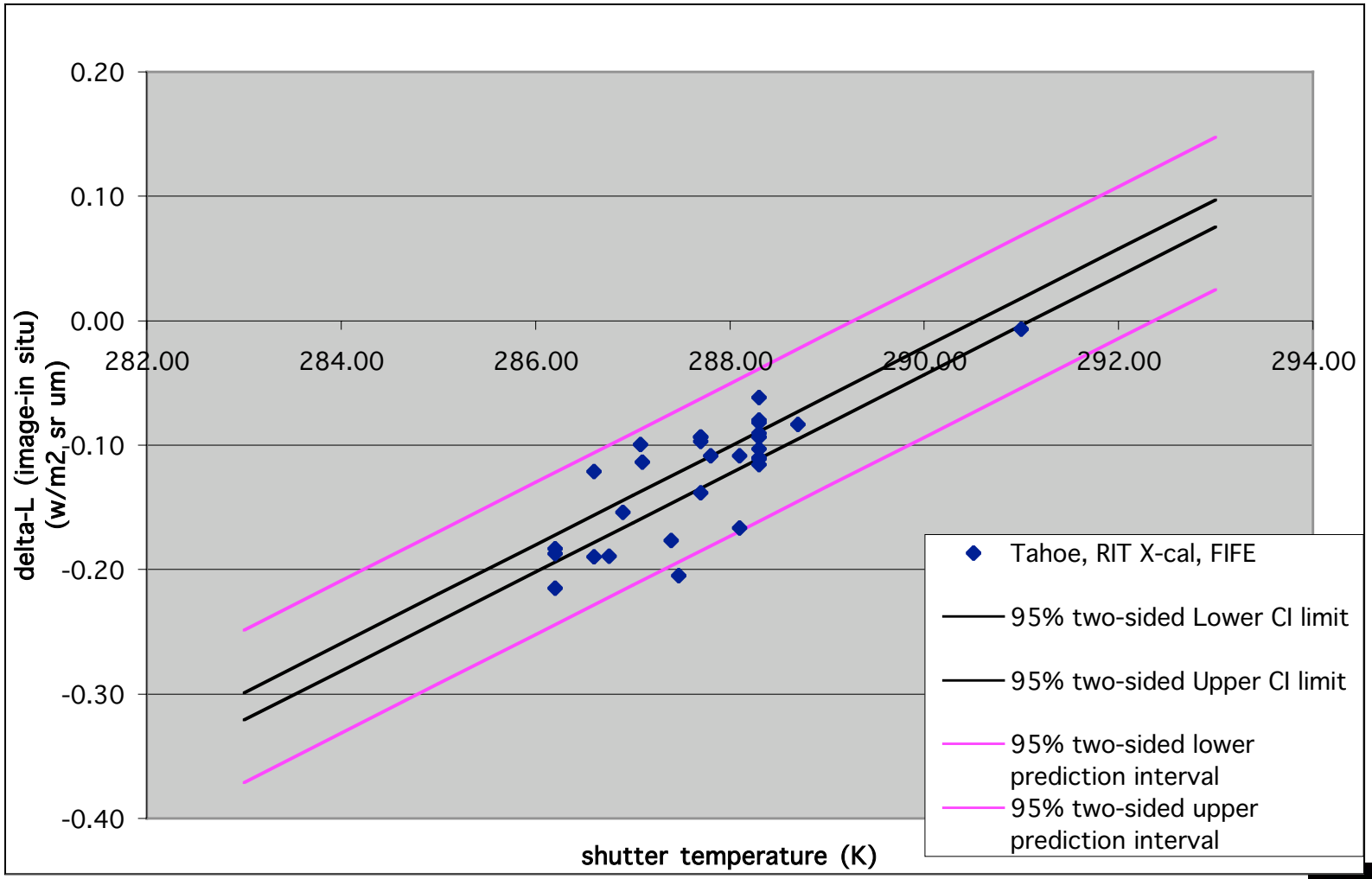




Landsat-5 TM Trended Shutter Temperature

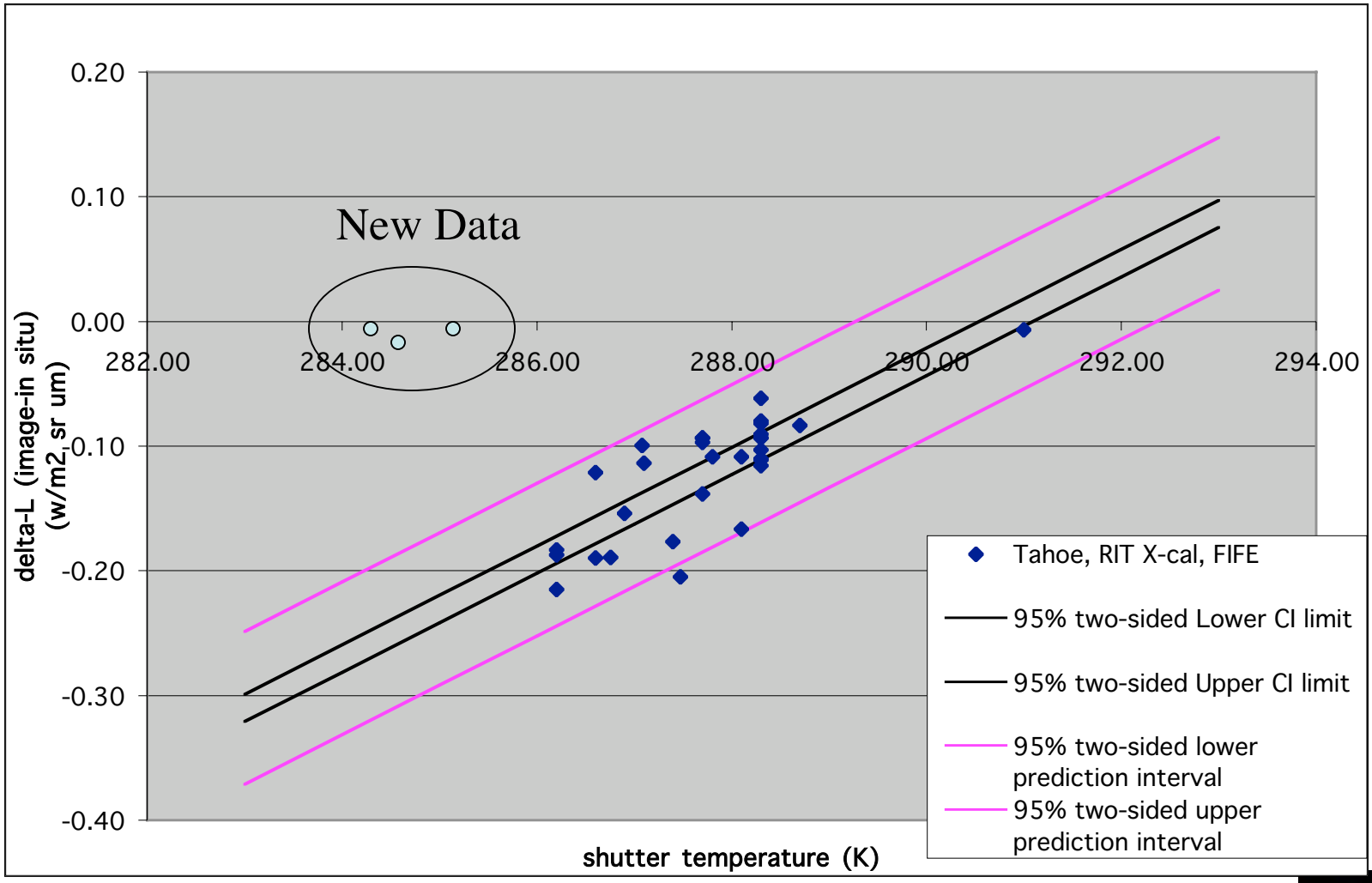


Shutter temperature vs. calibration delta-L



Removed RIT historical data

Shutter temperature vs. calibration delta-L with New JPL Tahoe Data



Landsat-4 TM Calibration Reconstruction Status

- Internal Calibrator data examined
- Outgassing Model Developed
- Results complicated by several year hiatus in L4 TM data collection (1983-1987)
- Cross calibration to L5 TM complicated by limited data and 8-day offset

Summary

- Landsat-7 ETM+ Reflective bands very stable, trends on order of 0.3%/year
- Landsat-7 ETM+ thermal band very stable-no significant gain change with time
  - SLC failure may have introduced bias (<1K)
- Landsat-5 TM reflective band calibration procedure has been updated
  - Now internally consistent and cross calibrated with Landsat-7 ETM+
- Landsat-5 TM thermal band has greater scatter relative to ground measurements-- circa 2K relative to 1K for ETM+
- Landsat-4 TM calibration reconstruction in progress